Smart Library Applications in Oman using iBeacon Technology: A Case Study

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ABSTRACT

Academic universities, like other institutions, are experiencing some challenges related to the increasing progress in information and communications technology that the world is witnessing, which has had a clear impact on changing the nature and work of libraries and information centers. Smartphones are one of the most important and popular modern communications devices among users. Recently, it has witnessed increasing use of smartphone in various areas of life due to their connectivity to the Internet and the fact that their prices are affordable for everyone. With that consequences it became necessary to exploit this technology in the field of libraries to invest in exchanging information, providing various library services, and keeping up to date with the technological developments. Among a list of cutting edge technologies iBeacon is one of the modern technologies that has experienced an expansion in use on different scales recently including public library. Therefore, this study aimed to apply this iBeacon technology in the library of the University of Nizwa. Since the technology is new in Arab libraries, linking it to a smartphone application to help the users to have easy access to the location of the books on the shelves, as well as informing the user of new arrival /information that make them interested about the library. In addition to receiving notifications of upcoming activities offered by the library and the latest books that have arrived. Further, it will also reduce the burden on the employee by answering the user's frequent questions on different library services. It will in fact, ensure the better services to the users and help the employee at the same time. Overall, this is will be an easy going path-way to achieve the required satisfaction with the library and its services from the end users and library authority. After extensive research and evaluation; in this paper; a number of suggestions has presented, such as the importance of the institution's support for the library to adopt various modern technologies to facilitate its services and increase its efficiency through iBeacon.

Keywords—witnessing, communication, university, library, technology

INTRODUCTION

With the development of technology and the acceleration of companies to excel in this field, many technologies have emerged that have contributed to improving work and meeting customer requirements in a timely manner and with the required quality, including spatial computing, which integrates the real and virtual world using computer vision to merge the two worlds.

The term spatial computing was coined in 2003 by Simon Greenwold, and it can be defined as a user interface in which technology is used to create a three-dimensional computer interface in which physical reality is changed by sending input information and obtaining outputs via cameras and sensors [1] after processing them in computers. It includes augmented, virtual, and mixed reality, in which there is an interaction between the real world and digital technology to highlight the result, and this is achieved using

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spatial programs and geographic information systems by collecting information via sensors with graphs to analyze and share the data [2].

The scope of spatial computing today is broad and includes education, healthcare, manufacturing, transportation, the automobile industry, etc. For example, healthcare experts are focusing on spatial computing technology to monitor diseases, and smart self-driving cars are using it to transport passengers to their destinations. It is also currently used in the areas of education and training on an institutional scale. Since it does not require different techniques and object configurations, it increases the speed of work, saves money, and improves safety because it determines the exact location of the object, thus enhancing customer satisfaction [1]. Spatial computing and iBeacon technology are related in the sense that both involve the use of technology to understand and interact with physical space.

In this study, we proposed an application which is relies on iBeacon technology in the University of Nizwa library to search for the location of the book on the library shelves and linking it via smartphone to the catalog application of the library's Koha system, which will enable the user to track the location of the book inside the library and find it among the shelves without resorting to the employee, as well as tracking books that are out of place. In addition to providing the library user with a set of information about newly arrived books and the activities that the library will hold once he is within the scope of the beacon. Location-based services can help return books to their correct places on the shelf by using Bluetooth technology, specifically the iBeacon technique, due to the impossibility of using GPS technology inside the library, linking it via the mobile application to determine geographical location, and making it available on mobile phones for both Android and iOS.

BACKGROUND

With the spread of the use of virtual reality, augmented reality, and mixed reality to include many applications and fields, many companies have begun using spatial computing to increase the interaction between humans and machines while including the surrounding environment and the real spaces of things.

Spatial computing and its applications:

The term spatial computing was first coined nearly 20 years ago [3], but the revolution in its applications has increased over the past four years to include many fields, including education and health care. In [1] paper, they review the functions of one of the spatial computing application devices, which is the ProjectDR device developed in the field of health care, which allows them to display various medical images, such as the results of magnetic resonance imaging and CT scans, directly on the patient's body, which gives a complete view of the internal anatomy of the body on the area to be treated, using a motion tracking unit equipped with cameras and infrared indicators on the patient's body with a device to display the three-dimensional images obtained in advance. Which helps in visualizing the surgery for the doctor and during the education and training of new doctors. As the researchers pointed out in the end, the system can be expanded to include a number of other screen technologies, as it has been integrated into many domains, including schools, medical colleges, laparoscopic operations, surgical scheduling, and others. Another application of spatial computing which call (Nearby Services), the researchers [4] indicated in their study that spatial computing is widely used to identify services close to the user and provide the effective search results he wants for himself using his current location around the world, thus providing him with the closest places available to him using the GPS system. The focus was on the use of a mobile phone application equipped with a global positioning system, and its goal is to improve the service of the application based on it by making it more flexible for the user and using the greatest number of surrounding parameters to provide more effective results. The way the application works depends on connecting nearby devices together and providing the largest amount of data using satellites. After applying his proposed algorithm, the researcher was able to improve the efficiency of the application, but there are some points that need

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expansion, such as the type of application and the economic background of the user.

In the field of applications in the educational aspect, the paper [5] reviewed the results of a case study on the use of spatial computing for mixed reality and its application in a fully remote classroom, where classes were conducted for 10 weeks over the Internet at a university using teleconferencing programs and MR spatial computing (Magic Leap One headsets) with an avatar-mediated social interaction application (Spatial). Through the interviews and questionnaires, they conducted with students, they reported that it provides a good experience and advantages different from traditional 2D classrooms, with a feeling similar to the presence of students and teachers in the same place and the ability to participate, collaborate, and present projects in a more realistic way. The researchers suggest further expanding its applicability to extended classes. The ability of devices to perceive their surrounding environment and represent it digitally is what spatial computing represents, which is an example of human-robot interaction, through which spatial computing is combined with sensing on mixed reality devices, which enables the robot to capture and understand human behaviors and then translate them into actions with spatial meaning. [6] Mobile robots were used in libraries as an application for spatial research, which is the focus of this study. Robots are used to perform many functions and operations, and in order to be able to navigate in an environment and avoid obstacles, they need to build and use a digital representation to understand the area, taking the form of a map which maintained by the robot to estimate where it is in space, in addition to the structure of the environment. Data about the world with spatial significance is embedded in a digital framework that aims to capture information about space and the digital devices within it as completely and accurately as possible. The researchers [6] implemented several prototype systems that use robots and mixed reality devices to provide new solutions for real-world applications over human-robot interaction. They include the spatial computing and egocentric sensing capabilities of mixed reality devices, approaches that may provide solutions for real-world robot use in commercial and research fields with possibilities for future research. Other applications in [7] as a case study focused on geographic information systems (GIS) applied in spatial computing that support solving spatial problems used on map layers. Using the Python language, researchers here present an alternative approach to spatial analysis that is based on the user's ability to ask questions about the environment rather than searching for and performing actions on map layers. This could therefore create new opportunities for programmers to develop applications and thus allow users to interact with spatial computing systems in a more interrogative way, thus obtaining more natural and productive results. The study produced a set of encouraging results that helped expand and improve some of the formal specifications of the basic concepts in the field, modify the calculations specified on them, and make them shorter and easier to understand.

iBeacon technology and its applications:

Moving on to the iBeacon technology and its various applications, which have begun to spread widely, the researcher [8] applied iBeacon technology with campus information, creating the uBeacon application compatible with the Android system, which was designed as a means for the user to interact with the smart campus system by receiving his information from the server directly after integrating it with it using the communication protocol (MQTT) when there is Signal, as it can be used in several services such as registering student attendance, moving around the campus, and other services, and it is similar to what was also indicated by [9], where the application aims to automate practices on campus using iBeacon with Bluetooth Low Energy (BLE) technology, which makes it Easy to implement and low cost to apply, the paper discusses possible applications in the campus environment such as indoor campus navigation, automatic attendance, and interactive learning activation that simulates the actual interaction between the student and the lecturer during the study process.

iBeacon and Bluetooth Low Energy applications in Arab and foreign libraries:

Speaking about the applications of iBeacon technology in foreign libraries, a study [10] reviewed the

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application of this technology in providing information services in the library. It aimed to identify the extent of user awareness among university libraries about iBeacon technology if it is applied and integrated with library services to provide advanced and smart services. To achieve this, the researcher conducted a field study in which a questionnaire was distributed. On a sample of 198 beneficiaries, one of the most prominent findings of the study was that there was a positive trend in the sample towards using iBeacon technology to benefit from it in library information services. Another application provided by [11], which is focused on developing and designing a special application for touring Virginia Tech University's Newman Library using iBeacon technology after the library saw the need to use it instead of QR Code technology in order to help the library's users get to know its sections and find its collections easily with the ability to specify locations. Equipment and a location for the 3D printing studio, as well as providing guidance to the hearing and visually impaired by displaying pictures, maps, and visual displays on their phones when they pass or approach the iBeacon device in the library, in addition to helping in answering all queries of users through the reference aids supported by the application.

On the part of Arab libraries, there were signs of applying this technology in some libraries, including [12] which is aim to study the possibility of benefiting from iBeacon technologies to develop the services of the Library of Alexandria as a model for applying iBeacon technology services in Arab libraries, considering that the University of Nizwa Library is one of the Arab academic libraries that is the subject of the current study, the researcher mentioned the services that benefited from the technology and the difference between it and GPS positioning technology, in addition to the problems and obstacles that this technology may lead to and how employees deal with modern technologies and accept them as a form of developing and facilitating various library services. As another application for Arab libraries, the library of King Abdulaziz University in Jeddah, as the researcher indicated in his study [13], to learn about its features, how it works, and its uses in the field of libraries, and to come up with a set of proposals that contribute to making the most of iBeacon technology. Being a relatively new technology and still in the process of application and development to discover its advantages and expand its use, there are a few Arab studies that study it in some detail on the technical side.

Smartphone applications in libraries:

Speaking of smartphone applications, in a study on the use of high-band Bluetooth technology in libraries and its application on smartphones, the researcher [14] conducted her Ph.D. thesis to study the possibility of applying iBeacon technology in the College of Nursing at Menoufia University by designing a smartphone application that facilitates library services for employees and users. Using an experimental approach, the researcher sought to study the extent to which users accept dealing with modern technologies in Arab libraries, the extent to which the librarian possesses the necessary skills to deal with technology, and the impact of that technology on work within the library. She concluded a set of results, the most important of which is the presence of a positive trend for users to benefit from this technology and the possibility of training on it. There are many difficulties, including financial and programming, to applying this technology and using it in the library, and she came up with many recommendations on the importance of moving towards applying modern technology in libraries and providing what is necessary for the institution to adopt these technologies, which contributes to facilitating various library services. In the same field of phone applications, the researcher [15] conducted a study on the use of smart phone applications in library guidance for user services, which was applied in Saudi academic libraries. The study aimed to urge Saudi libraries to apply iBeacon technology in their buildings, relying on the descriptive survey approach to collect data from the study sample, which included four central libraries in three universities with more than 700 students and employees, in order to develop guidance services for the user in a way that facilitates his use of the library facilities and thus reduces the burden on library workers and increases their job satisfaction, she found that most of the users' problems lie in their lack of knowledge of the new resources and activities offered by the library, as for the employee, it is the frequent repetition of questions by the

user, which is a problem that most previous studies have been exposed to. Therefore, applying this technology reduces the burden on the employee and reduces the user's waiting time for service. Since iBeacon technology is an Internet of Things technology, the researcher [16] conducted a study into the contributions of the Internet of Things to supporting smart libraries by applying iBeacon technology. Using the descriptive approach, the researcher sought to introduce this technology and explain its characteristics and advantages, as well as the extent to which it can be used and invested in the field of library services. She found that this technology constitutes an opportunity to improve the current situation of libraries and transform them into smart libraries, and thus the necessity of benefiting from the experiences of other libraries, especially foreign libraries that have previously adopted and applied this technology. And with the pace of business, there is always a demand for fast services in all their forms, and therefore managers in libraries seek to find a balance between the increase in books and the speed of searching. This is what the researcher [17] pointed out in his study, which describes the design of a system based on iBeacon technology to quickly move between library shelves to find books. One of their commonly used WeChat phone applications was used. By applying the system, opinion polls can be conducted about the library's activities, ensuring there are vacant places in the library before going there, and other services such as welcome and recommendations for new books.

Obstacles to using iBeacon:

Moving on to the problems and obstacles in applying the iBeacon technology, the study [18] aimed to uncover the various problems that stand as obstacles to the application of iBeacon technology while developing some solutions for them. One of its most important results was that the problem of privacy is one of the most prominent of these problems. The study also reviewed the requirements for employing iBeacon technology and how to design its applications, protocols, and methods for detecting signals and estimating distances. To end, the study presents various advanced applications of iBeacon technology.

After reviewing various published sources, there were only a few sources published about the application of iBeacon technology services in Arab libraries, and most of them were limited to exploiting this technology in a number of services, namely introducing the user to the library's activities, its recent activities, and newly arrived books; notifications of borrowed and overdue books; moving between library buildings or sections; and responding to frequently asked questions. As for applying the iBeacon technology and using it in the service of searching for the book's location among the library shelves, we did not find anything referring to it to the best of my knowledge. Therefore, this study seeks to present a proposal application for applying the technology iBeacon in the University of Nizwa Library to search for the location of the book among the shelves.

METHODOLOGY

This a case study conducted in University of Nizwa Library, using theoretical approach to collecting the data that published in the field of applying the iBeacon technology and propose a scenario to apply this technology in the library based on the study of this researcher that mentioned in the reference number [19]. However, iBeacon is a technology that relies on Bluetooth Low Energy and an accelerometer, it is not a physical product, developed by Apple iOS 7 devices and later versions that allows iPhones and tablets to search for nearby Bluetooth devices. Beacons are physical devices that send and receive Bluetooth Low Energy signals [20] that contain the person's location and directions. The technology uses software that processes these signals and acts as a beacon to guide the user to the location of the object. It was announced by Apple developers in 2013 [21]. In contrast, in 2015, Google announced its alternative to iBeacon, called Eddystone, which adds some different capabilities. Although very similar to iBeacon, Eddystone uses Google's Bluetooth 4.0 communication protocol. Then, it launched the Google Beacon platform, which

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includes the Proximity Beacon API designed to link content to individual beacons that can be retrieved by any app using the Nearby API in Android or Nearby library for iOS [22, 23].

The approach:

Particle Filtering on the user device:

The iOS app on the user's smartphone included a particle filter. Then the iBeacons were installed in an indoor setting. The user will be tracked constantly, and the app displays his estimated location. The unfiltered RSSI readings were sent into the particle filter. Using the path-loss model, RSSI data were transformed into distance between the beacons and the user device. In RSSI-based localization, the path-loss model is commonly utilized. The different parameters in the equation below were calibrated after rigorous experimentation to improve the localization accuracy. (RSSI = ?10nlog(d) + C) where n depicts the path-loss exponent, d shows the distance and C is the reference RSSI value at a area of 1m.

Particle Filtering on the server side:

The user smartphone that runs the iOS application will collect the RSSI values from different iBeacons around and forward it to a local Apache Tomcat Server which ran particle filtering algorithm by using the unfiltered RSSI values. So the result of the algorithm is the estimated user location.

Cascaded Filters on the server side

Using Particle filtering is the main algorithm for localization. But, for the cascaded filter part; the values of RSSI were filtered through KF, as a result the fluctuation can be reduce in the RSSI. The reduced fluctuation then can improve the localization accuracy and reduce the variation of the observed positions.

Data Sources:

- The status of the actuators (boolean) is determined by the user's movements in and out of the geofence.
- Actual position of the user in the (X, Y) grid
- Estimated position of the user in the (X, Y) grid

Data Analysis:

After completing all the experiments, the data related to the user's original location as well as estimated location obtained was compared using equation bellow. The average localization error was calculated as the difference between the actual location (X, Y) and the estimated (X<est>, Y<est>). n, equal to 11 in their experiments, was the total number of points that used as the actual position whereas (X) and (Y) were computed using the average of 10 measurements (estimates) for a particular point.

$$< Error >= \frac{\sum_{i=1}^{n} \sqrt{(X_i - X_{<est>})^2 + (Y_i - Y_{<est>})^2}}{n}$$

The average localization error, they calculated standard deviation of error for experiments in different scenarios with varuse number of particles, and iBeacons and to improve the accuracy of the algorithm they used the parameters of KF and EKF.

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EXPERIMENT DESIGN AND RESULTS

For the experiment we placed some beacons in an 11m × 6m distance due to the presence of obstacles, as well as tested the proposed system in a 1m × 1m space. Then utilized the developed iOS app which obtained the RSSI values from the iBeacons with the use of a particle filtering algorithm for indoor localization. Through the experiments altered the number of particles and iBeacons to locate the user.

Table 1: Devices information

Device	Apple iPhone 4s
Wireless Interface	Bluetooth V4.0 / 2.4GHz
Operating System	iOS 8.1
Beacons	Gimbal Series 10
Gimbal range	50 meters
Transmission Frequency	100 ms
Major Value	Yes
Minor Value	Yes

Figure 1; presents the average localization error in speace 1m×1m for a number of iBeacons. He also increased the number of iBeacons until the addition of more iBeacons did not improve any results or, in the worst case, affected the localization accuracy because of the interference among iBeacons. In a 1m×1m environment, he started with 3 iBeacons, and to improve the overall localization performance, he added 6 other iBeacons. The addition of the sixth iBeacon affected the localization accuracy adversely due to the fullness of the space with iBeacons, resulting in interference among the iBeacons, as shown in the tables.

And the lowest localization error is observed for 4 iBeacons and 1000 particles. Figure 2 shows the average localization error vs. number of iBeacons in an 11m × 6m space. As in the state of a 1m × 1m area, he started with 3 iBeacons in the space and continued increasing the number of iBeacons until it enhanced the localization accuracy. And when he added the 8th iBeacon to the area, it affected adversely the average localization error, which is why he did not add more iBeacons to the space. Tables 4, 5 show the average localization error with the standard deviation of localization error for a number of particles and iBeacons in an area of 11 m × 6m, and the minimum localization error of 0.97 meters was obtained with 1000 particles and 5 iBeacons.

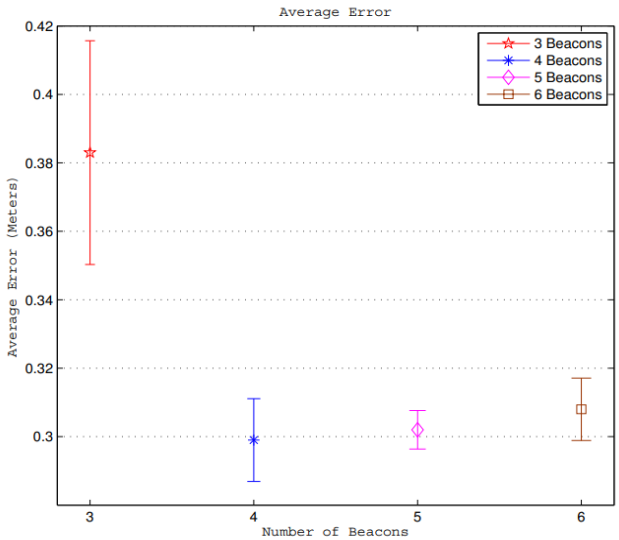

Figure 1: A number of particles for different number of iBeacons vs average error (1m × 1m)

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Table 2: Filtered particle on the user device with Localization error (meters) for several particles and iBeacons (1m × 1m)

Particles	Beacons			
	3	4	5	6
400	0.308	0.290	0.303	0.301
600	0.356	0.308	0.312	0.302
800	0.396	0.301	0.302	0.310
1000	0.384	0.276	0.298	0.316
1200	0.400	0.299	0.293	0.318
1400	0.403	0.289	0.307	0.315
1600	0.385	0.314	0.306	0.316
1800	0.407	0.298	0.299	0.291
2000	0.411	0.312	0.300	0.304

Table 3: iBeacons in (1m × 1m) environment with particle filtered on the user device and Standard Deviation of Localization error for several particles

Particles	Beacons			
	3	4	5	6
400	0.065	0.158	0.162	0.156
600	0.232	0.172	0.155	0.171
800	0.262	0.170	0.151	0.164
1000	0.273	0.178	0.164	0.152
1200	0.254	0.167	0.159	0.167
1400	0.249	0.167	0.163	0.156
1600	0.238	0.164	0.146	0.149
1800	0.245	0.172	0.175	0.181
2000	0.253	0.161	0.143	0.181

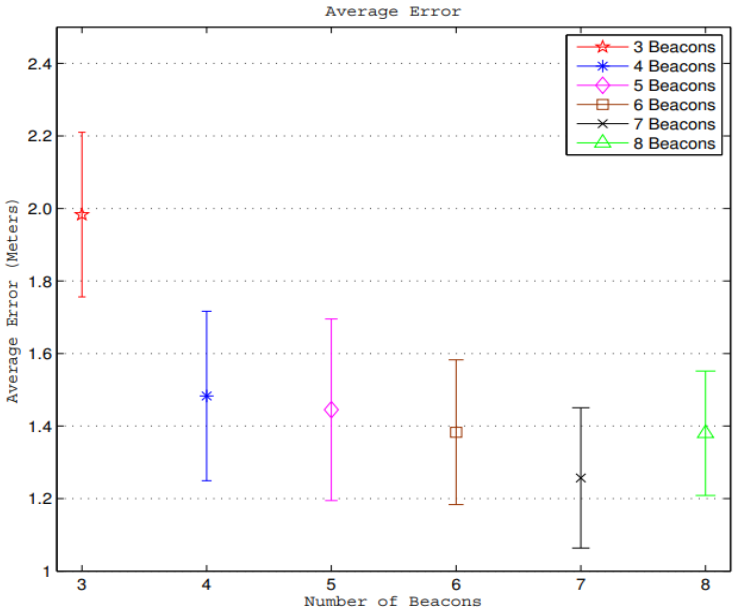

Figure 2: A number of particles for different number of iBeacons (11m × 6m) environment vs average error

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Table 4: A number of particles for different number of iBeacons for (11 m × 6m) with particle filter on the user device vs average error

Particles	Beacons					
	3	4	5	6	7	8
400	2.195	1.486	1.720	1.590	1.385	1.492
600	2.167	1.074	1.159	1.422	1.200	1.595
800	2.152	1.729	1.721	1.598	1.345	1.623
1000	1.736	1.802	0.975	1.284	1.220	1.432
1200	1.843	1.678	1.531	1.126	1.008	1.275
1400	2.262	1.507	1.575	1.639	1.442	1.180
1600	2.049	1.251	1.455	1.149	1.339	1.245
1800	1.774	1.368	1.540	1.208	1.362	1.168
2000	1.668	1.451	1.328	1.430	1.017	1.411

Table 5: A number of particles for different number of iBeacons (11 m × 6m) with particle filter on the user device vs Standard Deviation of error

Particles	Beacons					
	3	4	5	6	7	8
400	0.333	0.913	1.005	1.288	0.641	1.399
600	0.996	0.600	0.868	1.164	0.850	1.176
800	0.394	1.041	0.825	1.045	0.672	1.378
1000	0.441	1.082	0.885	1.189	1.144	0.815
1200	0.473	1.034	0.692	0.890	1.020	1.009
1400	0.261	0.733	0.890	1.660	1.042	0.763
1600	0.295	0.640	0.724	0.943	0.637	0.681
1800	0.669	0.698	0.872	0.948	1.000	0.815
2000	0.561	0.458	0.919	1.296	0.977	0.962

The computational overhead of computing the particles on the user's devices may cause the battery to deplete more quickly. Furthermore, the device's restricted processing power may have an impact on the algorithm's performance. As a result, the researcher used a local server to conduct the particle filtering method for estimating the user position.

During the researcher's experiments, he found that the beacon's localization accuracy can be affected by the position of the beacons. While the positioning of the beacons greatly depends on the environment and the rooms where they are placed for localization, it is important to consider where the beacons should be placed and the suitable heights for them rather than placing them at lower heights, which can affect the localization accuracy and make the measurement more erroneous. There is no standerd model for placement of the beacons as the sites and rooms might vary and if they have to deploy number of beacons and different position based on the size of the room, number of people, and obstacles. There are general guidelines that can be obtained for deploying beacons:

- Place the iBeacon away from any obstructions or interfering equipment.

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- Place beacons at a reasonable height to avoid obstacles, but not too high as this affects localization, especially in a 2D environment, because the RSSI value reduces as the height of the beacons increases (the distance between the beacons and the user increases).
- For accurate indoor localization, at least three iBeacons are necessary.
- Keep it away from potential obstacles
- If a certain place in the room has a significant localization error, deploy beacons to increase localization accuracy

As a result he infer from the trials that beacon deployment should be well planned based on the environment place. Because the characteristics and architecture of the deployment space differ from one environment to the next, it is critical to conduct a site survey and study the environment before deploying the beacons in a topology that maximizes localization accuracy. This enhances localization accuracy and decreases localization error in that particular area of the room [24]. By reviewing the experience of one of the researchers in applying iBeacon technology, this experience can be adopted and applied in the proposed system, which links iBeacon to the book sites in the library, and then change what is necessary and conduct tests to reach the desired result.

After such long experiment we may recap, applying the technology in practice may produce a number of results that are beneficial to the library, including:

- Reducing the burden on the loan and reference service employee
- The ease of use of the phone by the user contributes to making the application more acceptable to the beneficiary and thus using it continuously when needed
- The users rely on themselves to obtain the book without having to search for help or wait for a long time
- Ease of finding scattered books and returning them to their correct place on the shelvesThe technology
- is low-cost and thus does not put pressure on the institution’s budget Feeling comfortable when using
- applications on the phone
- Expanding the use of technology to include a number of other services provided by the libraryKeeping
- pace with advances in technology

CONCLUSION

With the rapid development of spatial computing technology, communications technology, and accompanying technologies, we found increasing acceptance by libraries to adopt these technologies that will contribute to facilitating works. And it can be easily achieved with the emergence of technologies such as iBeacon, which are low-cost and versatile. Undoubtable it will move forward the library to enhance the user experience and open a door to interact with the library in a way that is more smooth and more interactive which will bring bilateral convenience. In this paper, the iBeacon technology, its components, and method of operation were identified. The overall result is more appealing to apply the technology in the University of Nizwa Library. Surely it will be extremely beneficial the employee and the users. Easy and quick mitigation of service request for both parties e.g. users and library employee will be ensured. Further, it will reduce the burden on the employee and provide the user with several enhanced facilities/features provided by the technology. Based on the findings of this research; we are also proposing to link it to the library system “Koha” to track the location of books on the shelves as the iBeacon application highly recommended to determine the user’s location. We are also reached to a number of hypothetical results, including:

- Encouraging libraries to adopt modern technologies
- Encouraging employees and students to accept these technologies to facilitate various expected

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services
- Increase the speed of response to various requirements which will help to reach-out beneficiary satisfaction.

After extensive evaluation of literature, method and its results; we can confidently conclude that our proposed iBeacon technology will be able to serve extremely-well which leads a library to reach to modern service standard.

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